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ABSTRACT

This research was designed to elucidate the activity structures and routines of elementary mathematics teachers by describing what they are, analyzing their frequency and duration, analyzing the functions that routines serve for the cognitive processes of teachers, and beginning to model the chains of routines and their fit with planned or spontaneous actions that make up a lesson. Five "expert" teachers and four novice student teachers, along with their classes, comprised the sample. They were observed over a 3-1/2 month period, with note-taking, videotapes and transcribed interviews providing data. For each teacher, transcribed notes and interviews were analyzed and broken down into action records giving duration, action of student, action of teacher, and a name for the action. For two experts and one novice teacher, a more detailed analysis was made of goal structures, routines, and actions. Discussion of the data focuses on activity structures and presentations, with goals and routines given extended discussion. Actions of two "expert" teachers are contrasted with that of one novice teacher. Implications and importance of the research are also discussed. (MNS)

Routines in Expert Math Teachers' Thoughts and Actions

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In the context of studying the cognitive processes of expert mathematics teachers while teaching, we have found the notion of a teaching agenda useful. An agenda is the operational plan for a particular class. It includes the traditional "lesson plan", but it also includes the decision elements that permit a continual updating and revision of the agenda, activity structures, and scripted operational routines. The research described here is designed to elucidate the activity structures and routines by 1) describing what they are; 2) analyzing their frequency and duration; 3) analyzing the functions that routines serve for the cognitive processes of teachers; and 4) beginning to model the chains of routines and their fit with spontaneous actions or planned original actions that make up a lesson.

If we consider teaching as an ill-structured dynamic task environment (Simon, 1978) we can analyze both the nature of that task environment, the strategies involved in the execution of plans carried out in it (Hayes-Roth & Hayes-Roth, 1978; Stefik, 1980)and the nature of spontaneous actions. Expert teachers can be seen as operating with a well specified but flexible agenda that includes sequences of activities, general goals, alternative strategies, and routines.

The lesson consists of several action segments called activity structures each one of which contains several routines. An activity structure is a well-known recurrent unit of task and management actions within the classroom, shaped by the behavior of teachers and students (Bossert, 1978; Berliner, 1983; Berliner, King, Rubin, & Fisher, 1981). A routine is a smallish pattern of actions and speech that is recognized by both teacher and students and can be used repeatedly across several activity structures (Bromme, 1982). For example, the paper passing out routine is often initiated by the teacher walking across the front row of the room with a pad of paper and tearing off some for each child in the front row. The first child in the column then takes one piece and passes the rest back through columns of the classroom. It's a quick and efficient way of distributing paper and occurs for: shared presentations, guided and monitored practice and tests. Verbal routines also exist in the form of choral patterns of response or turn taking without repeated explanation.

Activity structure analysis has been a prevalent notion in sociology and the sociology of education for some time. However, it was the work of Bossert (1981) that brought it to the attention of researchers in education, especially those involved with process product issues. Berliner (1983) and his colleagues (Berliner, et al., 1981) recast the notions of activity structures, merging them with the notion of the opportunity to receive particular types of instruction. Their initial analysis, while limited in some respects goes a great distance towards making the activity structure notion pay off in terms of predicting student growth. What it does not address as clearly is how these activity structures and the embedded routines within a single teacher's repertoire

can be utilized to reduce the cognitive load carried at any one time and expand the teacher's facility to deal with nine unpredictable elements. This latter notion has been hinted at by Bromme (1982).

Methods and Population

The population used in this study consisted of a group of "expert" teachers and a group of novices (student teachers in their last semester of school). Experts were identified by reviewing the growth scores of students over a five year period and selecting the classrooms at each grade that appeared at the top each year (within the top 15 of each grade). Classrooms in which the final achievement was above the top 20 percent were chosen from among the high growth classes. Two of these teachers' records were chosen for a second level of more detailed analysis. All of the teachers taught in self-contained classrooms and two taught an additional math section. Median class size was 28. The students in the classrooms came from families who ranged from lower class to lower middle class. One classroom was all white, two were all black, and two were integrated. The four student teachers were chosen from a pool of twenty available. The four were considered to be the best students and were teaching fourth grade. The most competent of the four was used for the second analysis of routines, presented here. The student teachers taught in two integrated middle class schools.

Data gathering. Each teacher was observed over a three and one-half month period. The pattern of observation was as follows: observation of three classes with open ended notes; one week of observation of continuous classes, with an all day observation taken once during the week; three separate days of observation in which pre and post interviews

were taken, asking the teacher about his or her plans for that period; and finally three to five separate videotapes of classes in which preplanning interviews and post interviews that included a stimulated recall based on the videotape were taken. Further interviews about their math knowledge and the math knowledge of their students were also considered. Thus, approximately 25% of the math classes taught during the three and one-half months were observed and over 8% of the year's classes were observed.

Analysis. Two types of data were generated: the raw videotapes and the transcribed notes and interviews. For each teacher the notes were read and broken into action records giving duration, action of student, action of teacher, and a name for the action. Each action was defined and the definition used as a basis for analyzing more transcriptions or tapes (Footnote 2). The total set of codable data was used for each teacher and medians and ranges of time spent in each activity calculated. For two of the experts and one novice we selected one tape for a more detailed analysis of the goal structures, routines and actions. The tapes were selected for recording quality and teachers' comfort with the session (thus the first tape was rarely used). In analyzing these tapes information is drawn from the stimulated recall, from the teacher interviews and from the other teacher discussions.

Results. Both the action segments of teachers and students were considered in the first analysis. Thus, while there could be a category called presentation which would cover both presentation with teacher alone, presentation followed by recitation, and presentation that continuously used both individual and group responses, I have chosen to divide these into categories called presentation and shared presentation.

The presentation function and teacher actions are similar in both but the child's action is very different in the two and the opportunity for feedback and probability of attention is quite different.

Activity structures. Fifteen categories were used to describe the actions of the expert teachers. The median and ranges for each category are presented in Table 1. As times are given it is useful to know that the median length of class is 41 minutes. The median is used not only for its resistance to outliers but because it tends to answer the question: for an activity that occurs more often than not what is the duration of time for which it occurs when it occurs.

Presentation refers to a teacher's uninterrupted explanation of new or very recently learned material - students listen. All teachers use it almost daily and it lasts approximately 8 minutes. Shared presentation refers to teacher presenting, usually through questioning or with the help of a child or children orally or at the board. Often it includes manipulatives or game-like atmosphere. All teachers use it, it is done daily, and lasts approximately 14 minutes. Drill is timed rehearsal of facts by students either orally, in writing or at the board, usually paced by the teacher. Most teachers use it at least weekly for around 4 minutes. Game drill is timed by virtue of a race between groups or individuals, it involves the rehearsal of facts by students in a loud, usually public, atmosphere, is used by only two teachers, on rare occasions it lasts 12 minutes. Homework refers to checking and collecting homework or seatwork. The teacher may call out the problems or numbers, students answer either chorally or simply in turns or write problems on the board. The actual collection or check off for work is sometimes done

during math class. Most teachers take care of homework either at the beginning or end of the day, or by a pass-in check file system. However, rapid review and correction of in-class work or homework takes about 7.5 minutes. Under some circumstances it can be the cue to a presentation. Guided practice is a form of seatwork in which students work on presented problems at desks or board, but with teacher guidance. The teacher has students doing five or fewer problems at a time, keeps up a fairly continuous explanation of the problem, and usually gives immediate feedback to the group on the answers to problems. This is interspersed with semi-public tutoring. It is often the lead-in to monitored practice. It is done by all teachers, almost daily, and lasts approximately 11 minutes. Monitored practice is the more traditional seatwork but involves the teacher moving about the room, checking and tutoring while students work. We saw only one teacher on one occasion assign material to the class and then sit down and correct papers. This latter would be called practice. Monitored practice is done by all teachers, almost daily, and lasts approximately 15 minutes. Tutorials are extended presentations to a few students while other students are working either at the blackboard or at seats. It lasts around two or three minutes for any one group, but a teacher does it for an average of 24 minutes a class when it is done. Review refers to a shared presentation of obviously known material (it is not simply the beginning of a presentation although it often occurs then). It is done by most teachers, when necessary, instead of a presentation but is not done daily or weekly. It lasts approximately 5.5 minutes. Tests are self-explanatory and occur rarely. Transition refers to the change from one activity to another. The teacher usually is listing several actions and students are executing them. There are usually three or four a period and for expert teachers are very brief, often less than thirty

seconds. The total transition time is around three minutes per period.

While both the within and between variance is considerable, teachers are consistent in the key elements of presentation, shared presentation, and monitored and guided practice. Students of expert teachers are very engaged during short presentations (over 4 minutes and restlessness starts) and shared presentations. The students are also quite engaged in learning activities during guided practice - less so during monitored practice.

The significant aspects of these activity arrangements lie with their effectiveness in increasing the amount of time that a student is directly engaged in learning or practicing math and receiving feedback; in reducing the cognitive load for a teacher; and in establishing a frame that permits the easy transmission of information in mutually known and recognized settings. While some broad generalities are useful, such as the fact that expert teachers use little time in transition, the more fine grained results are of greater importance.

Expert teachers construct the math lesson around a three staged core of actions. This core consists of a set of activities that move from total teacher control to independent student work. The teachers start with a presentation of information which frequently involves students in some form of focused discussion, moves to public shared working out of problems, then to very interactive seatwork and occasionally to independent seatwork. This is a progression that has been recognized by several authors, Good (1983) among them, as indicative of good teaching. In our observations, teachers used review, drill, tutoring, and testing on an irregular basis, but frequently enough that students behaved

predicatably in them.

Novice teachers' behaviors tend to be quite different, they get involved in long wordy presentations or attempted shared presentations. The key feature seems to be that lessons have one or two activity structures and the routines for each have to be build anew each class since there is no continuity across classes. Rarely is the class involved in a guided practice. Thus, while all our expert teachers regularly assigned homework, they did so only if there had been two rehearsals (guided and monitored practice or text book plus work book) in class. The novice teachers used homework to finish an incomplete lesson.

Expert teachers believe that students are more interested and have a higher rate of achievement when the type of action and action setting change frequently. They may be correct, for they have little trouble getting through the text material and doing the enrichment work with even the lowest track group. They manage this with seatwork, for example, because students are never left to do large chunks of busy work devoid of instruction and feedback. For example, one teacher routinely starts by assigning two problems and having the students stand when they are finished. She uses the standing to observe the slowest child and then goes to that child for tutoring during the next round of four problems. This both paces and gives rapid feedback on performance to all the children.

The expert teacher has with the class a large repertoire of activity structures and usually several forms of each one. It even seems that there is an occasionally used script of teaching a new activity structure. The main feature of the experts' use is that once established these units

are: (a) very flexible, (b) order can be shifted and pieces taken from one segment and applied to another, (c) little or no monitoring of execution is required, (d) little or no explanation is required for carrying them out. In contrast the novice does not work in a routine or habitual way so each portion of a lesson is different from the next and each day is different. Students must then be instructed as to their roles and the teacher must take time and energy to explain each action.

Although experts do make alterations in order to maintain interest, they also have effective well rehearsed activity segments, which should not be confused with rigidity or boredom. Routine can be boring, but most of our teachers used the variety of activities and routines available to reduce monotony, and to accomplish similar ends with multiple modes. An analogy might be that one is likely to have fun under many situations if one can play tennis, squash, racket ball, badminton and play ping pong well, than if one spends a long time chasing missed tennis balls in a meandering, marginally competent way and can do no other racket sport.

In the following sections the basic frame of an activity structure is used to analyze in a more fine grained way the driving goals and supporting routines for each lesson.

An Analysis of Goals and Routines

In considering the way in which routines are used, two lessons will be reviewed in detail and a third, a composite of the novice, will be discussed at appropriate points to contrast how the same activities are handled. The first lesson is a lesson on mixed numbers, by Ms. Longbranch. The class starts with homework being corrected, then a brief

review of terms, followed by a shared presentation of how to change a mixed number to a fraction. The shared presentation is continued using a public practice format for a considerable part of the class with several groups of children being called to the board and returning to their seats. Guided practice is started with some children at their desks while others work at the board. The class ends with enrichment worksheets being done.

When we unpack this rather ordinary lesson, the amount of cognitive processing on the part of the teacher and the successful accomplishment of tasks becomes clearer. Strings of actions combine together in a recognizable pattern, an activity structure. Each action segment has as a goal its own completion and frequently contains the prerequisite to continue, either in the simple form of "When A is done go to B" or in the more complex situation of A generating as a side product information to be recorded and then read in B, C or D. The first clear cut goal is to get the homework corrected and handed in. Within this there are three subgoals: to establish who did or did not do their work (indolents post their names on the board); to correct the work; to assess the general success rate.

For each activity structure shown the basic goal is identified and the subgoals or components are listed. Many of the activities and routines are initiated by a very short verbal phrase that alerts students to either change ("Erase, be seated.") or the action itself ("Page 169.") For each subgoal the actions used to accomplish the goal are identified and the functions and or outcomes are reported. A function is the consequence of an action; it is not identical to the goal or subgoal but may meet known or the constraints. An outcome or product is listed only if the consequence of an action produces something that must be carried

forward into another goal or subgoal, in some cases these outcomes are themselves goals. Thus, an individual child's failure to perform in one action may produce a goal to continuously tutor that child throughout all other activities. The basic goals for the lesson do not stand alone but both receive and produce products from other activity structures.

The expert attains his or her goals by using two schemas, an action schema and an information schema. The action schema follows the three subgoals closely. First, the teacher calls attendance to which each child responds yes or provides an explanation for missing homework. If the child has not done the work, s/he puts his/her name on the blackboard. An informational schema for the teacher is also being activated (I-SCHEMA) containing a list of students who did not do their work. Second, she calls the problem out loud and the students giving the answer chorally. If the chorus weakens, the teacher learns that that item is difficult. I-SCHEMA records the key item features. Last, she calls out numbers of items missed starting from zero and stopping when there are consecutively no hands raised. I-SCHEMA records those students who miss a lot of items.

Figure 1 shows the actions related to achieving the first goal. The teacher gives the cue, "Ok, set 43". Attendance is rapidly called - each child answers yes or writes their name on the blackboard - Time to complete, approximately 30 seconds. The routine is well rehearsed and universally known. The action provides information and exerts a monitoring and public control function. An outcome is that the teacher knows who has not done the work.

Insert Figure 1 - Expert Homework Here

The second subgoal is to correct the homework. The students take colored pencils out and respond chorally with the correct answer, a fraction in lowest terms, as the teacher calls the problem "1/12 + 1/12" "2/12 or 1/6". Time to complete, 106 seconds. The teacher's calling out the problem serves the function of pacing the class through and reinforcing the pairing of problem and answer. A second function is to note if any of the items produced problems for the group as a whole. This is determined by the situation in which multiple answers are shouted. Thus, at this point in the lesson through the use of two of the three homework checking routines the teacher knows which children she doesn't know about (namely the ones who didn't do their homework) and which problems, if any, create difficulties.

The last subgoal is to discover which of the children had difficulty in general with the assignment. This is done in 30 seconds by calling out the number of problems missed and having children raise their hands. The homework (or class work) activity structure accomplishes a lot in a little time and produces information that can be easily carried forward into the rest of the lesson. The routines used are attendance response, choral response, and hand raising. The teacher has reduced the amount of potential processing and has kept a simple component of the lesson simple. In teachers who are less successful we often see large amounts of time and intellect expended on just such a simple component.

Figure 1A shows a procedural analysis of the goals that must be accomplished in order for the goal of homework check to be fulfilled. The three goals are displayed with their respective test for completion and the procedures used to actually accomplish the goals.

Figure 2 - Novice Homework Check - Here

In contrast, a novice teacher doing the homework check activity behaves somewhat differently. Figure 2 shows the homework check activity for one novice which was an extended activity (6 minutes) in which the goal was reached somewhat indirectly and without the type of teacher control present in the previous example. The homework activity is made up of two of the same subgoals, the first identifying who did homework, and second, orally correcting the problems. For the first subgoal, the novice stood up at the front of the room and asked, "Who doesn't have their homework?" The students did one of the following: stayed seated and held up completed work; stood up, walked to the teacher and said either they had it or did not have it; called out from their seats that they didn't have it. The novice teacher responded that homework is important and there are no acceptable excuses, and marked on a posted sheet whether work is completed or not. She included no summary action, thus, she did not have accurate information about the homework status of everyone. The I-SCHEMA is not being used or is not working. The novice uses a less effective question, does not have a routine to obtain the information, and is not maintaining control of the flow of information. The students, in an attempt to comply with the somewhat unclear request respond in a variety of confusing ways. Not only is her attempt at accomplishing the first subgoal time-consuming, it takes 85 seconds. It is also the case that she is unable to retain the information in memory to carry it forward and may have incomplete information as we see in the next section.

The second goal is to correct the problems. This can be done as the expert did it, or by the teacher collecting the work and correcting it and returning it, or some other combination. The second segment of the novice's homework check is to correct the problems. She calls on students to give the answers for correction. The novice calls out a set of problem numbers (1-10) and assigns a child to call out the answers as the teacher calls the problem number. The student slowly calls out the answers in order. (The first child chosen is the lowest in the class, does not have her work done and is doing it in her head.) Thus for the first 10 problem answers the teacher has lost control of pace and correctness of answer, however, it is only when the child fails on the sixth problem that the novice realizes the student has not done her homework. (To get to the seventh problem took 105 seconds.) The novice then calls on four separate children each of whom gives the answer to one problem. The rest of the class is checking the work at their desks. The novice then picks her main "trouble maker" to do the next block of 10. The rationale for choosing this child was that it was the first time the child had volunteered for anything. He misses one problem but then continues - going through ten problems in 70 seconds. The last child chosen goes through the sequence quickly but the sound of the child saying the problem number and answer next to each other is confusing, (e.g. 24, 27; 28,64).

The novice teacher clearly has the beginning of a strategy for getting homework checked. First she does it (she did not earlier in her teaching and another novice did not even check the homework, leading to another set of difficulties). Second, she realizes that she should have some structure and that time is a constraint. During each cycle she starts by having the child pace it, then she takes over the pacing.

Returning to the expert's lesson, the second goal is to present the topic of the lesson. For this class the presentation and shared presentation activity structures are always used. Lesson presentation of new material - mixed numbers - is outlined in Figure 3. There are three subgoals: The first is to review the labels (vocabulary) needed, the second is to present the task, and the third is to demonstrate the algorithm. Overlaid on these three subgoals are several systems of constraints which themselves help construct the solution: keep the lesson moving (Footnote 3), get through the task (Footnote 4), call on different children (Footnote 5), watch for the stragglers and help them (Footnote 6), keep interest and action up (Footnote 7), don't embarrass children (Footnote 8).

Figure 3 and 3A - Expert Presentation - Here

To review the labels the teacher asks for a definition. She selects one of the weakest children, Connie, to answer. This is both to encourage Connie and to do a bottom level check - if a low child can get it, the lesson can move rapidly. Connie does not get it and her failure produces another subgoal (2A1), which is to check on her for the rest of the period. The teacher then moves to one of her strongest students for the definition - she also fails. The teacher tries again with a middle level - he fails. Teacher then calls on a top child who is correct, repeats the definition after the student and has the class rehearse it chorally. This is an analysis of the action schema, While the I-Schema is being used to construct goal 2A, further analysis is needed of this segment to analyze how the I-Schema is functioning.

In the time constraint system Ms. Longbranch is behind. For the second subgoal of the presentation, the definition of how to change mixed numbers to fractions, she now must move ahead, increase the pace but still maintain involvement. She does this by having a choral reading of the rule from the rule cards at the front of the board. So within 1 1/2 minutes she has reviewed the definitions, introduced an algorithm and rehearsed it. (It probably should be pointed out that the prior lesson involved extensive work with drawing mixed numbers and talking about 1 1/2 of a sandwich and 3/2 of a sandwich, etc.) Ms. Longbranch is now ready to use a routine of public practice where a problem can be put on the board and a child is called on to guide the teacher orally through the operation. Ms. Longbranch shares control slightly by permitting volunteers but calls on one child at a time to do each of the three steps of the algorithm.

The first problem (Subgoal 2C) is 2 1/2, a relatively easy problem; a child (a middle level anxious child) is called on to perform a part of the algorithm (multiply the whole number by the denominator), the teacher follows the rule for the second step while the student dictates to her (add the numerator). These actions are carefully watched by the students both because it is the first real demonstration of the algorithm and because of the relative excitement of watching a student tell the teacher what to do. At the third part of the algorithm Ms. Longbranch asks for the answer to "keep the same denominator" and both 2 and 4 are shouted out by the entire class. This is an interesting failure in routine. Ms. Longbranch always gives a problem then calls a name. When a name is not called a choral answer is usually expected. In this case Ms. Longbranch meant to continue with the child but the time had been too long. She

instead got a choral answer which she interpreted as shouting out. She pulled the kids together by telling them to sit up, put pencils down, and not to call out. The mutual misunderstanding was not recognized (either when it occurred or later when she viewed the tape) by the teacher who simply saw the event as one where she was trying to keep the children in control. ("And I like, as you have seen so far, I like order in my room. I can't stand that when they start all hollering out.") The second problem given to the students is 3 2/5 which is assigned to a top level child. He goes through all the steps smoothly, thus publicly rehearsing the algorithm. To check how the lesson has landed she goes to the weakest child (from goal 2A1) and rehearses the steps for changing 2 3/4 to an improper fraction. As the child gives the answers Ms. Longbranch writes the answers on the board. The actions produce a third example on the board, rehearsal of the algorithm, and a check of the weakest child, who is caught up. The teacher is now ready to begin public practice on the blackboard with groups of students.

Figure 4 - Goal 3 - Here

Goal 3 is summarized in Figure 4. The goal is to have public practice at the blackboard. That is, the goal is the action. The action itself helps to meet the larger goal of going through a lesson. The activity structure is still part of a shared presentation as this particular event involves only teacher generated problems not dittos or books. The routines are: assigning to the board, student monitoring of board performance, explanation of answers. The first action is to call students to the board. This is done by calling names of children. Before

the children reach the board the problem 3 1/3 is called out. At this moment Ms. Longbranch must shift attention from the six children she has assigned to those that are seated. She will continuously "read" these children for signs of restlessness, confusion or inattentiveness - those at the board are under public control now, and actually need less attention than the others. The students at the board write their solution to the problem and one child solves the problem orally, thus rehearsing the algorithm. As Ms. Longranch is watching the seated group and tutoring she sees Everett make a comment to one child at the board. Ms. Longbranch assumes it's negative and sends Everett to the board as a "if you're so smart, share it with all of us" reprimand. This action reinforces the belief that she is all seeing and the norms accompanying board work routines. One of which is mistakes must be constructively dealt with, not made fun of. After the 3 1/3 problem is finished the teacher asks "Everybody else correct? Erase? Put 5 and 2/6. Everett, you tell us this time. What are you going to do?") Everett forgets to add the numerator and his failure produces a "seee" from the teacher. Ms. Longbranch constructed a win win situation. If he didn't get it she could point out his error, if he did she could rehearse the correct answer.

To move to the second cycle, she calls for the students to erase and be seated, identifies the second group, retaining Ryan, a weak child, calls out the new problem, 4 1/2, and checks with Connie to define the problems (as mixed numbers) (Goal 2A1). In one breath she has literally shifted almost half of the class around, checked on a goal carried forward, given special attention to a child who needs it and made progress toward completing her goal. In the second cycle of students she reviews the rules and gets an answer from a seated child to retain attention. The

activity is completed with an "erase, be seated".

Figure 5 - Expert Transition - Here

The next activity is a transition, shown in Figure 5 (it is the third one of the class) from the presentation to guided practice. There are four separate subgoals: get children at the board seated, get books out, distribute paper, and send second group to board. This is a particularly interesting one minute segment because it demonstrates the effective call up of four routines, none involving interactive responses, all of which are simply executed. The teacher's closing statement from the previous activity, "Erase and be seated", initiates the transition. This phrase seems to cue all the students to listen for a list of instructions. As the six children move back to their seats the teacher simultaneously says "take out your books, turn to page 169" and passes the paper out to each child in the first row. The books emerge and are opened and paper passes over heads one by one, to the last row. There is a brief pause and the teacher says, "Nicholas' row (column) to the board - first three to the front, second three to the back."

Figure 6 Here - Guided Practice - Here

The last activity segment to be described is guided practice (See Figure 6). In the first portion of this activity some children are at the board while others are seated; all are working out problems from the book. There are six cycles of problems and one switch. The first subgoal is to give a problem, solve it and answer it while keeping seated children

involved. This is done by having the teacher identify the problem number, having a seated student read it aloud while the ones at the board do it. A second seated child states the answer and a third explains. This system keeps the pace going, involves the whole class and rehearses the work.

Figure 7 - Novice Presentation - Here

The novice's presentation does not proceed with the same fluidity, nor does she accomplish as much as the expert (See Figure 7). The novice, Ms. John, is introducing the concept of multiplication (although the students know their times tables through at least fours). She starts with the subgoal of arousing interest. Her actions are (a) to tell the students that this is so important that if they miss it they will be lost for the rest of the year. (b) She then attempts to have the students chorally read the word multiplication - only a few participate. (c) This is followed by a long speech about some word problems they wrote out several days earlier, one of which required repeated addition. The responses to these three verbal actions, each one of which ended with a type of rhetorical question, have been less and less. At this point Ms. John says, "Am I talking to myself?" - which is a response to the failure of the choral routine. A second subgoal is to introduce chips as a way of showing multiplication but she has failed to complete the presentation subgoals of defining terms and showing importance. She recognizes this and says, "Not now oh no, no, no, no, no." The students chorally go "aw aw". Ms. John is in some minor trouble at this point but proceeds. She has had a break down in the general execution of her plan, but she recovers well.

She points to the board and says, "Here is your typical multi---plic---ation prob---lem" and then refers to part of addition problems and parts of multiplication problems - "the two numbers are called what?" A modest choral response reads "factors" from the board; but when she asks for product she has lost them and they are reprimanded for not paying attention. Ms. John has talked a lot, the students are bored and the key points of the lesson are still several minutes away. She and the students don't work well together. She has not used known routines often nor developed consistent cues. Her action schema fails occasionally and her informational one is just beginning to emerge - her processing is loaded down with elements that are automatic for the expert.

A second expert lesson given by Ms. Wall is on equivalent fractions. It will be reviewed briefly. This lesson starts with the correction of homework and a brief review of the algorithm. The rest of the class is devoted to a game drill of concentration in which each child has at least two chances to practice using the algorithm to determine if the fractions they uncovered are equivalent. As in the first expert's lesson, the first goal of this lesson is to get the homework corrected. The subgoals also are the same: determining completion and the success rate.

The actions in the second lesson are slightly different. The teacher begins by telling them to get out their homework. She then gives a misinterpreted cue: "Steven?"" and gets the response, "Here", obviously calling up the straight attendance routine. The teacher corrects the routine by immediately saying, "Do you have it?" She gets the correct response and continues calling attendance. She marks the response in a book she is holding. The homework check shown in Figure 8 is completed in 55 seconds.

Figure 8 - Second Expert Homework -Here

The second action is, as in the first lesson, to correct the homework. The teacher calls out an individual child's name and the problem. The child responds with the answer.During the 165 seconds it takes to check the problem the teacher asks "checking work?" The teacher paces the work by calling out the problem and monitors the class' responses by her reminder to "check work". The calling of individual children's names allows the teacher to reach her informational subgoal of determining which children had difficulty with the work. It is three children who she has described as "daydreamers" who miss the homework problems.

The last action is to assess the success rate of the class. She does this by asking "All right?" and making a quick scan of the room to determine whose hands were raised. This takes five seconds and in conjunction with the information obtained during the homework correction gives the teacher information she needs later.

The second goal of the lesson is to review the algorithm to be used, namely to find factors of a fraction in order to reduce it.The teacher uses a shared presentation for the review. To pace the lesson, the teacher has written six fractions, not in lowest terms, on the board. The teacher calls on a high student to read the fraction. She gives them a cue from a previous lesson: "Ask the first question?" The kids give her a choral response, "Is 3 a factor of 6?" She then asks Kelly, a middle child, what the next step is and when Kelly fails, immediately calls on a

consistently high child who is right. The class solves the problem chorally. She calls for an individual response on the second fraction, gets a choral response and promptly regains her control by loudly repeating the child's name. The class goes through the remaining five fractions using a mixture of individual and choral responses. The teacher checks on the three children who missed homework problems (all of them could answer correctly), twice asks for information "any questions so far?" and thoroughly rehearses the algorithm.

Ms. Wall then moves into the third segment of the lesson, a game drill activity in which the children practice using the algorithm by deciding if the fractions on the two cards they turned over are equivalent. She describes the game, sets the rules, and then practices by turning over two cards for the class to determine chorally if they are equivalent. Four teams are set up. The game proceeds with each child turning over two cards, writing the fractions on the board and then orally going through the steps (Ask the question; what are the factors?) before solving the problems. Class interest remains high throughout the game, with choral response requested by the teacher when the child at the board has difficulty. The game and class end simultaneously with the class clapping and the teacher telling them "you are all winners because you could reduce the fractions and that's what I wanted."

Two experts teaching two lessons on different topics differ. But both use familiar grouping of verbal and physical behaviors to facilitate the smooth running of the class. There is little confusion in cues. What does get confused is quickly fixed. Without feeling rushed both experts complete their lessons and provide between 40 and 50 opportunities for rehearsal of the newly learned material. The alternative of having

students do 50 problems at their seats without reinforcement, or feedback is grim indeed.

The differences between novices and experts with respect to class structure do not center solely around activity structures but around routines. The novice spends a little more time than experts presenting but not much, considerably more time than experts in guided practice and less time in monitored practice. There is, however, a constantly changing pattern of how these activities get done. One day there is a lengthy lecture by the novice, the next day endless filling in of a chart on the blackboard of number facts, and the next day two quizzes sandwiching a presentation. The failure of routines exists in part because there is little or no repetition of them and in part because the novice has not worked them out.

The weakness in the novice's use of routines is apparent in the following 15 minute excerpt from one of the last lessons Ms. John taught (it was the last lesson videotaped). The novice had given the students a 2 minute test (the 4 multiplication table) and collected the test papers (1 1/2 minutes). At this point the children were talking and moving around the room. Ms. John asked, "Does everyone have page 108?" She immediately asked if everyone had paper and the children called out, "No." There was no routine for passing out paper so the novice took a pad and walked around the class handing each child a piece of paper. Almost three minutes passed between the time Ms. John instructed the children to open their books and when, after her third repetition of the cue to open books, she began the presentation. The children were still talking, standing up and moving around the room. Ms. John, without any further cue, began the shared presentation. The shared presentation was characterized by

restlessness and calling out on the part of the children, which led to several teacher reminders about not talking. She did not effectively use a routine for either individual or choral responses. The amount of calling out increased after she consciously wrote a problem incorrectly (6 * - 8 as opposed to 8 - 6) on the board, and the children called out to correct her.

The shared presentation (6 minutes) was followed by a transition to the second test of the class. The novice followed a management statement to several children with "Does everyone have a piece of paper in front of them?" Some children called out, "Yes"; a few walked to the front to get paper. Ms. John said, "Turn it over. Close your book." She repeated that they should turn the paper over two more times and the children told her they haven't written on the paper. (She handed out the paper before the shared presentation but did not give any instructions to the children about what they should do with it. They did not write down the problems she covered during the shared presentation.) Ms. John explained the speed drill which was to follow, told them a second time to close their books, described how she wanted the problems written and the time the speed drill would take. As she was explaining she realized that they needed their books and told them to open them. The children complained that she had just told them to close their books. She apologized and asked "Isn't anyone with me?" A number of kids called out "No"; one said "Yes"; a number followed with "Yes". Ms. John then explained that she wanted accuracy, not speed, and told them they would have 2 1/2 minutes. The children asked her how to set up their paper and she told them to number the problems; then she changed her mind and told them, "As long as you can keep track of the problems." Just as she was about to start the drill, she

told the class they would only have 2 minutes, not 2 1/2 minutes, since they were running late.

The novice has used a jerky non-progressive structuring of activity structures -test, transition, shared presentation, transition, speeded (?) drill, stop. There are several failures in planning (should the books be opened or closed, is the last test/drill timed or not) and failures in routines (distribution of paper, choral recitation, individual recitation). The novice has a list of actions for herself but no comparable list for the students. All of Ms. John's cognitive effort is going into "doing" the pieces. She has nothing left over to order the segments smoothly, analyze or direct students' activities.

Implications and importance. The expert's lesson can be characterized as an action agenda consisting of a list of action segments. In the case of the first expert, the lesson equals: homework check, presentation, public practice, guided practice, monitored practice. Each segment has a substantive and unique content and a consistent knowledge base which is accessed for its completion. Each segment needs certain unique information in order to function; the routines within the segment either produce the information (who has homework) or read the information recorded from the outcomes of actions occurring in prior segments (is there a particular type of problem generating difficulty in the homework?). The information schema which retains and makes available information throughout the course of the lesson seems to be arranged very efficiently - the default position is no information needed. Thus, in the homework structure there is no information carried forward if everyone did their homework, no serious problems arise, and no one is in trouble over all. The schema lists information with critical properties appended so

that information can be assembled in redundant lists for use as needed throughout the lesson and for modification if necessary of more stable knowledge especially about children. Throughout the lesson the teacher is seeking and using information about the progress of students and the progress of subject matter coverage.

When we consider the massive amount of information that teachers and students must filter through in the course of a single math class, it becomes clear that some techniques must be used to structure the information and limit its complexity. This structuring occurs in part by dividing the 40 minute time of a class into action segments in which the overt behaviors are routinized. The new material can then be plugged into these segments. (This routinization means teachers do not need to take time from instruction to explain how to do board work, for example.) A part of the new material is preplanned, while another part is a response to the teacher's on-the-spot reading of the way the preplanned segments are going. The use of routines means the teacher has freed herself or himself to focus on the important and/or dynamic features of the material to be transmitted and the information from the students about how the lesson is progressing. Each teacher has three or four variants on each of the approximately 15 routines that are used. The expert teachers retain clearly defined information in the I-Schema and are in control of the agenda. New teachers are less able both to obtain and to retain information as well as to maintain control of the agenda. New teachers can benefit from information about different routines, methods of teaching them to students, and ways of using them effectively to maintain student interest. The use of routines also reduces the cognitive processing for the teacher and provides them with the intellectual and temporal room

needed to handle the dynamic portions of the lesson.

Students also benefit from the presence of routines. They can follow instructions and catch up because the sequence of behavior is familiar. They have more time to concentrate on the content of the lesson, or if they prefer, to let their minds wander. The student is relieved of both an interpretation and decision making element (what am I supposed to do with these six sheets of paper, which book).

This type of analysis of routines and activity segments is a useful way of starting to understand how teachers and students deal with a dynamic ill- structured task setting. Routines and activity segments constrain some of the elements by making them more or less static, and transform some of the tasks into highly standard elements calling up entire repertoires of mutually understood behaviors. The next exciting aspect to examine is how teachers and students deal with the dynamic and substantive elements of a lesson.

This extended analysis of expert performances has in one sense, not discovered anything "new" since like the sculpture lying locked within the stone, routines and activity structures have been used by teachers for many years. They have not, however, been made explicit. We know that good lessons have segments - something teachers "know" at some intuitive level. We know that experts generate and present information efficiently throughout the lesson. Their utilization of the information seems to accomplish multiple interlocking goals leading to a successful and cohesive lesson. We are now in a position to show novices not only the structure of a smoothly running lesson but the goals and constraints served by specific actions and arrangements.

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Footnotes

1. The author wishes to acknowledge the critical (both senses) help of James Greeno, Carla Weidman, and Cheryl Figura.

2. Although many of our definitions were similar to those used by Berliner and his colleagues, there were some differences in the consideration of "seatwork". We observed that only one teacher out of 12 ever used seatwork in the way Berliner and others define it (students alone working silently at desk, teacher correcting papers and generally not interacting). The majority of our teachers use this time as a chance to guide students closely through the steps of problems, giving individual or small group lessons, and pacing the group through a lesson, sometimes selecting problems that indicate an interesting feature.

3. Ms. Longbranch's concern about keeping the lesson moving is exemplified in the following excerpts: Interviewer: "What are the advantages of using choral check that you did for homework & for this?" Ms. Longbranch: "It's quick. It's very quick." (12/14/81; lines 401-403) Ms. Longbranch: "...it seems the way I have math scheduled I only have that 40 minutes so I really have to know what I'm doing. I have to have my 40 minutes organized." (11/19/81; lines 201-205) Ms. Longbranch: "...my math is 40 minutes...I can never drag math out for a couple of extra minutes." (1/6/82; lines 244-245).

4. Ms. Longbranch's underlying constraint of getting through the task is expressed in this quote of 12/3/81, lines 342-347, "...I don't have this written down anywhere, but in my mind I have it. I'm going to be finished with fractions before Christmas. I have to be, you know, to get on. So I'll just pace myself now so that I will get finished.

5. Ms. Longbranch tries to call on different children: "...everyone doesn't get to the board every day. But most of them do." (1/6/82; lines 291-292) "I think I was trying to get all the children to the board that I thought would have any difficulty at all." (12/14/81; lines 151-153)

6. One important concern is to watch for stragglers and give them additional help: "...I can tell (the ones that have trouble), they're always the last ones to stand up. So I know they need special attention." (11/24/81; lines 38-41).. "But usually the ones who have trouble will get to the board that day. The better ones will get turns, you know, every day, or three..." (12/11/81; lines 447-451). Then when you see the same person is always the last one getting up, well you know he or she is really having a tough time of it." (12/14/81; lines 358-361).

7. Ms. Longbranch is operating within the constraint of keeping the children interested and action moving: "There's no specific reason why I have them stand - just to keep them moving,...". (1/6/82; lines 462-464) "I feel like if I don't have them keep moving constantly, or doing something constantly, their attention span, I don't care how good they are, it just floats away.

(1/6/82; lines 475-478)

8. Ms. Longbranch always avoids embarrassing children: "I don't always pick out the poor ones, or else they'll know for sure ... you know, & I feel bad and then they won't want to go to the board. This way, everyone wants to go to the board." (12/11/81; lines 439-441;443-445). "And they hate to be the last ones sitting down. But I never point that out that they're the last ones." (12/14/81; lines 351-355)

Constraints: Reinforce doing homework
Keep pace moving
Keep attention
Watch for Ryan & Connie

Expert - 12/14/81

Goal 1 Homework Check

Subgoal 1A - Who has it? Time ~ 30 seconds.

- action: T call attendance - * Cue
  S say yes or put name on board
- function : monitors
- outcome : knowledge of who has not done work
  = carry foreward

Subgoal 1B - Correct work. Time 106 seconds.

- action: T calls out problems
  Ss call out answers - correcting pencils
- function : Paces, both groups have information,
  keep attention

Interruption - "How many reduced it to 1/6?"

Subgoal 1C - How many got how many correct? Time 22 seconds.

- action: T calls number perfect
  then number incorrect (2,3,4,...)
  Ss raise hands
- function : monitors, summarizes
- outcome : Students who got several wrong
  noted and carried foreward.

Conclusion Cue: *Pass to the front, put your books in your desk.

Figure 1. Expert Homework

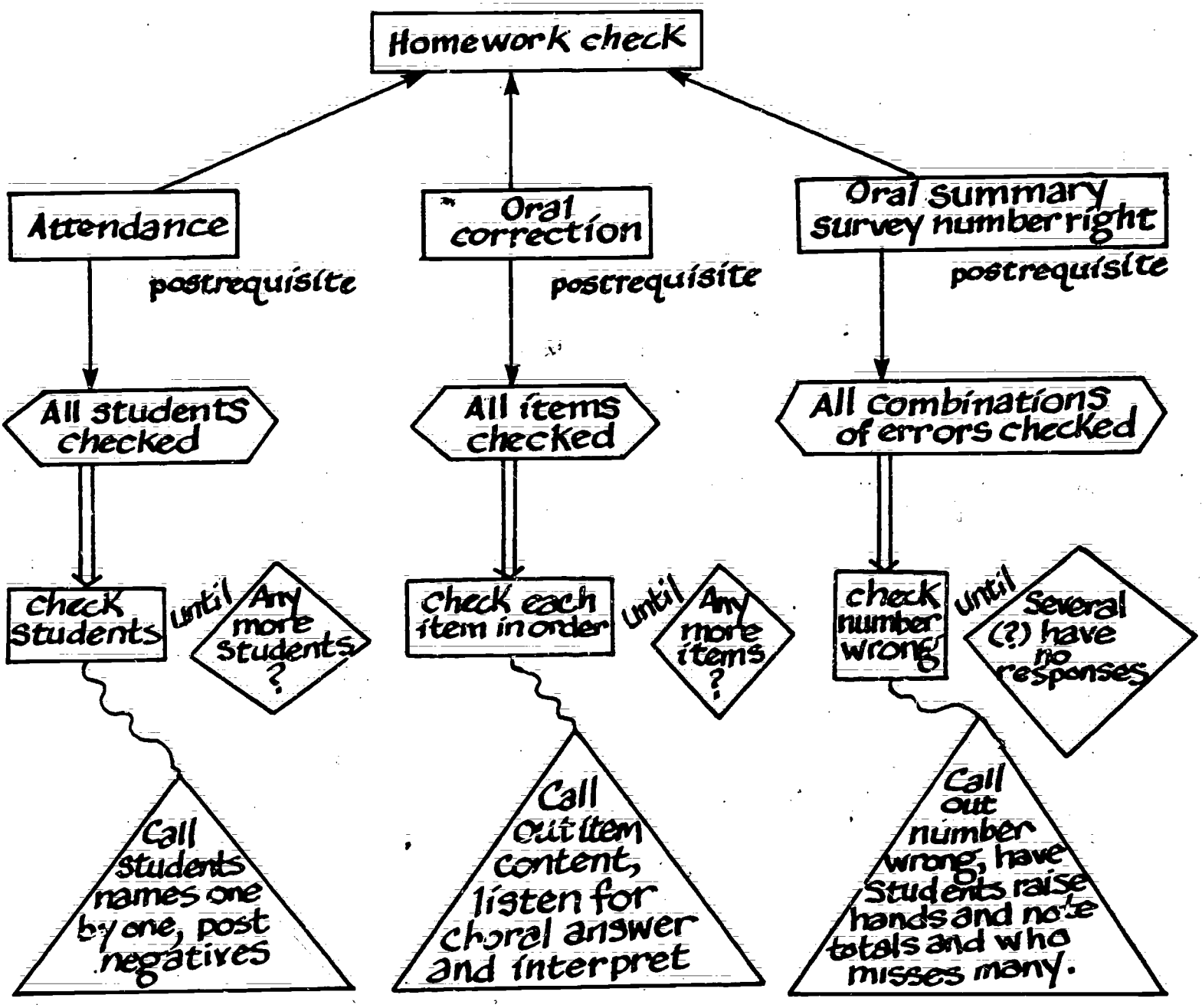

Figure 1 A. Procedural scheme for homework

Constraints: Reinforce doing homework
Call on students
Who rarely volunteers

Novice

Goal 1 Homework Check

Subgoal 1A - Who doesn't have it - 85 seconds.

action: T mark names on sheet at board

function : monitor homework

outcome : inadequate information about homework completion

Subgoal 1B - Correct work - 275 seconds.

action: T calls out problem #
gives set of problems or 1 problem to individual child
Stops calling out problem #

Interruption: Child answering does not have homework

S give answers
raise hand to volunteer

function : moves in and out of pacing, information

outcome : learns another child does not have homework

Conclusion Cue: *Clear Desks

Figure 2. Novice Homework

Constraints: Keep lesson moving
Complete task
Call on different children
Watch for stragglers
Keep up interest
Do not embarrass child

Goal 2 Presentation - Time 4 1/2 minutes

- Subgoal 2A: Define a mixed number
  - action: T asks for definition
    weak child is selected - fails
  - function:: involves students,
    check on first child
  - outcome: : Goal 2A1 - Check on Connie
  - action: T calls on Tracy
    Child fails - confused
  - action: T calls on Chris Brown
    Child fails - confused
  - action: Tiffany called on - gets it, ...
    T repeats definition, writes 2 1/2 on board.
    Ss choral repeat
    - function: Get definition across
      Don't waste time
  - Outcome: Time is lost - make it up
    Goal 2A2
- Subgoal 2B: Define operation of changing a
  fraction to a mixed number.
  - action: Teacher leads choral reading of rule
  - function: Clearly state algorithm, sacrifice
    student involvement for time
  - outcome: Time is caught up - goal 2A2 is met

Figure 3. Expert Presentation

Subgoal 2C: Demonstrate Rules: Select student, select problem - 1st iteration

Problem 1 - 2½

- action: T puts 2½ on board
  says rule - part 1 - calls on strong student, Terry
  Ss misspeaks but says it correctly
  T executes
- function : T controls fit between rule and action and involves students
- action : T says rule - part 2 - calls same student
  Ss adds numerator, states answer
  T executes
- function : Same
- action : T says rule - part 3 - and pauses
  Ss chorally respond, in part incorrectly

Interruption: Teacher calls to order and reprimands

- function: Keep students obedient

Subgoal 2C: Demonstrate rules: 2nd iteration

Problem 2 - 3 2/5

- action: T puts problem on board 3 2/5
  Calls on middle child (Everett)
  Ss says rules and executes
  T writes, pacing through each step
- function : 2nd clean demonstration, mid level check, more independence
- outcome : Success means can try on a lower student

Subgoal 2C: Demonstrate rules: 3rd iteration

Problem 3 - 2 3/4

- action: T puts problem on board
  calls on Connie
  T calls for rule (step by step)
  Connie executes
  T writes reinforces last step
- function : Check weakest child, check for success of rule presentation
- outcome : Success - Move on.

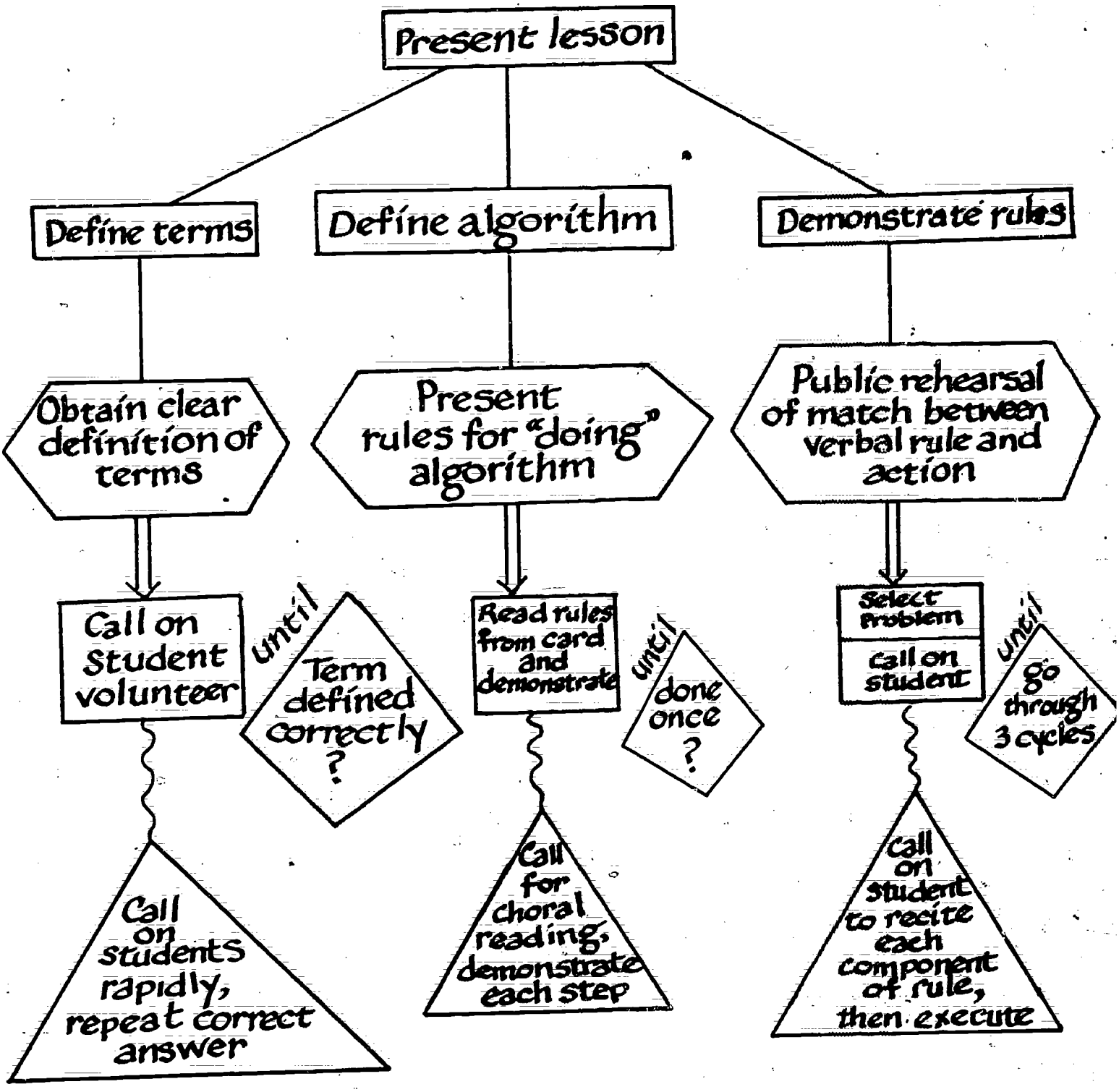

Figure 3A. Procedural scheme for presentation

Goal 3 Public practice: Time 4 1/2 minutes
Rehearse algorithm - 2 cycles Select Problem
Select Students
Orchestrate

Subgoal 3A: Set up board

action: T selects six students by name
T assigns to boards
T selects problem - 3 1/3
T asks for definition of type of number
Ss choral response
Ss at board do problem
T respond: walks through problem with child at the board

function : fun, public rehearsal

Subgoal 3B: Monitor seated students (cycles) in parallel

action: T watch students to see if paying attention

Interruption - catches a student commenting to one at the board - assigns him to the board too

function : Keep seated attending, punish inappropriate behavior,

action : T select 2nd problem - 5 2/6
T calls on punished child to perform
S makes minor error
T does problem publicly and corrects
*erase be seated
call wave two

function : Public rehearsal and public chastisement

Figure 4. Expert Public Practice

Subgoal 3C, 2A and 2B: Move to second cycle, rehearse

action: T *"Erase be seated", calls names to go to board
Group 1 sits
Group 2 goes to board - Keeps Ryan
T calls 4 1/2

(2A): T - to 2A1 - "What kind of number?" to Connie, seated
S gives answer - slowly with prompts

(3C & 2B): T to another - (Terry at board) How do we change
S gives algorithm, and answer
T repeats answer
Ss do at board - Teacher corrects

function : Keep pace moving, keep action going, rehearse lesson topic

outcomes : Changed groups, algorithm is firm, can change to practice

action : T says - 6 3/5
Calls on seated to define steps,
Continues oral problem solution
Ss at board do problem

Alright, erase, be seated.

Constraints: Time
Keep Control

Goal 4 Transition: To move from one action, the presentation to another, the guided practice with all students working.

Subgoal 4A: Get group at board seated

action: T says "be seated"*
Ss go to own seats

Subgoal 4B: Get books out

action: T says "take out your books
turn to page 169."
Ss open desks take out books, open them

Subgoal 4C: Distribute papers, set up

action: teacher takes pad, walks across front of room, tears off several sheets and hands all to first child in column
says, "fold the paper"
Ss take one and pass back
Ss fold paper into 16 sections

Subgoal 4D: Get group to board

action: T calls Nicholas' column, three to front three to side
Ss go to board

Figure 5. Expert Transition

Constraints: Keep pace
Involve all
Keep group together

Goal 5 Guided Practice. To have entire class rehearse changing mixed numbers to fractions, with less teacher guidance.

7 Cycles

Subgoal 5A - Give problem, solve problem, correct

action:
T in first block, problem 16
T and reads problem (1 1/3)
S reads problem
T call on child to answer
S gives answer (seated)
T call for explanation
S explains (seated)
T how many have ___?
scans

function : Start action, tells children at board problem, reinforces problem for seated, problem corrected

Problem list for cycles 2 & 3 (1 2/3, 2 1/4)

On cycle 2 Connie (2A1) is tutored at board

Subgoal 5B and D - Switch children

action:
T erase, be seated, list called for board
Ss do

Subgoal 5C - Same as 6A for three problems

End here but class continues

Figure 6. Guided Practice

Novice 11-30-82

Transition is first followed by explanation of video equipment.

Goal 1 Presentation - Time 3 1/2 minutes

Subgoal 1A - Introduce muliplication by arousing interest, giving terms.

action: T directs attention to board
calls for choral response

S few respond

function : involve students (fail)

action : T reminds them of word problems several days earlier.
Calls for choral affirmation

S No response

T "Am I talking to myself?"

function : Remind students of other lesson, Reintroduce problem, motivate students

action : T prepare to hand out chips
Changes mind

outcome : Do not change to another subgoal

Subgoal 1B - Define terms in multiplication

action: T directs attention to board
Calls for choral response

S several students respond

Interruption: T catches students looking around - "Get your eyes up here".

Figure 7. Novice Presentation

function : Keep attention

Subgoal 1C - Demonstrate Importance

action: T shows them speed they need when doing times tables

S complains she will forget tables

T refuses to accept complaint that they will forget

function : encourage students to learn tables (partial success)

Present level of competency beyond students

outcome : Distracting argument
Time lost
Thread lost

Constraints: Reinforce doing homework
Keep pace moving
Get information on weaker students
Give feedback on homework
Keep attention

Expert 2

Goal 1 Homework Check

Subgoal 1A - Who has it? Time ~ 55 seconds.

- action: T call attendance *Miscue correction, "Who has it?" check off name in book
  S "Yes" or "Yes ma'am"
- function : monitors
- outcome : knowledge of who has done work - carry forward

Subgoal 1B - Correct work. Time ~ 165 seconds.

- action: T calls out problem, name reminds them to check
  S individual answers
- function : paces, information about individual students, keep attention
- outcomes : student who missed problems noted and carried forward

Subgoal 1C - Who had them all right? Time ~ 5 seconds.

- action: T "All right?"
  S raise hands
- function : monitors, information

Conclusion Cue: *Look at the board

Figure 8. Second Expert Homework